Sugar Beet Performance and Interactions with Planting Date, Genotype, and Harvest Date

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ABSTRACT

Producers and processors have lengthened the sugar beet (*Beta vulgaris* L.) factory campaign by beginning harvest about 1 mo earlier. Agronomic practices may need to be adjusted to maximize yield and quality of sugar beet harvested earlier. The objective was to describe yield and quality relationships between dates of planting and harvest among 18 sugar beet genotypes. The experiment was conducted at the University of Wyoming Research and Extension Center near Powell, WY, during 1992 and 1993 on a Garland clay loam (fine-loamy over sandy or sandy-skeletal, mixed, mesic Typic Haplargids). Treatments consisted of five planting dates between 30 March and 8 June, and four harvest dates every 2 wk beginning 10 September. When averaged across all years, genotypes, and harvest dates, a delay in emergence of 46 d decreased root yield 38% (from 52.5 to 32.3 Mg ha^{-1}), sugar content 4% (183 to 175 g kg^{-1}), and recoverable sucrose 42% (9.25 to 5.34 Mg ha^{-1}). Delaying planting 46 d increased loss to molasses by 21% (7.75 to 9.41 g kg^{-1}). Root yield varied 18% among sugar beet genotypes (40.9–50.1 Mg ha^{-1}), sugar content varied 6% (173–185 g kg^{-1}), loss to molasses varied 13% (7.90–9.10 g kg^{-1}), and recoverable sucrose varied 14% (7.14–8.33 Mg ha^{-1}). Over the 43-d harvest period, root yield increased 22% (from 41.1 to 50.2 Mg ha^{-1}), sugar content 15% (165 to 190 g kg^{-1}), and recoverable sucrose 45% (6.41 to 9.28 Mg ha^{-1}). Over the harvest period, loss to molasses decreased 21% (from 9.10 to 7.12 g kg^{-1}). The relationships for both yield and quality between planting and harvest dates was linear and nearly parallel. Genotypic differences for yield and quality were greatest on early planting dates as compared with later planting dates. Recoverable sucrose ranking of genotypes at the beginning of harvest was similar at the end of harvest. Producers should consider planting high root yield genotypes in early planted fields that are harvested late, thereby taking advantage of the entire growing season, and genotypes with average root yield and above-average sugar content should be used for late planted or early harvested fields.

As SUGAR BEET processors lengthen the factory campaign of refining roots into sucrose, producers are being paid incentives to begin harvesting about 1 mo prior to optimum root yield and quality. Identifying agronomic practices that improve yield and quality with early harvest of what could be considered an immature crop would benefit both producers and processors.

Sugar beet maturity is often indicated by leaf yellowing and crown shrinking. Total recoverable sucrose accumulation follows a rather consistent pattern, with the greatest rates of increase between late July and early September (Carter and Traveller, 1981). Many agronomic factors are thought to influence maturity, such as N fertilizer rate (Draycott et al., 1973; Lee et al., 1987; Lee and Schmehl, 1988), genotype (Halvorson and Hartman, 1980), and planting date (Hull and Webb, 1970; Smit, 1993), but it is difficult to manage for maturity in a commercial field. The most important factor affecting maturation appears to be seasonal climatic changes (Loomis et al., 1971).

Optimum early growth is important for proper maturing of sugar beets (Boiffin et al., 1992). In North America, sugar beets are usually planted as early as possible in the spring. Delayed spring planting or replanting due to inclement weather, pests, or equipment breakdowns results in progressively less recoverable sucrose at harvest (Hull and Webb, 1970).

With late planting or replanting, producers must examine the economic trade-offs between lower sugar beet yield and other cropping system alternatives. Every year, producers have to decide whether to replant a sugar beet stand that has poor emergence due to cold, wet soils, crusted soils, or pesticide or fertilizer injury. In other situations, producers must decide whether to replant when insects or mechanical and weather damages (such as sand blasting, hail, or frost) destroy plants in established stands. Producers also have to make late-planting decisions when wet soils or machine breakdowns prevent getting into fields on schedule.

The effect of planting date on harvest date is not understood (Jaggard et al., 1983). One hypothesis is that early planted sugar beets mature early and should be harvested early, while late planted sugar beets should be harvested later, after the field has undergone a more complete maturing process (Draycott et al., 1973). Another hypothesis is that early planted sugar beets have greater yield and quality potential and should be harvested after later planted sugar beets of lower production potential (Holmes and Adams, 1966). Finally, Hull and Webb (1970) and Scott et al. (1973) concluded that yield increases at the same amount during fall harvest, regardless of planting date.

Some sugar beet genotypes have been promoted as high sugar content genotypes adapted for early harvest. Large genotype differences in crown tissue production (Halvorson et al., 1978; Halvorson and Hartman, 1980) and development rate may cause quality differences between genotypes and thus require different harvesting

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Table 1. Planting date, genotype and harvest date effect on yield and quality of sugar beet grown at Powell, WY, during 1992.

			Brei impurities				
Production factor	**Root yield**	**Sugar content**	**Na**	**K**	**Amino-N**	**Sucrose loss to molasses**	**Recoverable sucrose**
	Mg ha^{-1}	g kg^{-1}		mg kg^{-1}		g kg^{-1}	Mg ha^{-1}
Planting, first irrigation, and emergence dates (P)							
30 March, 20 April, 1 May	59.0	193	164	1200	155	6.89	11.00
16 April, 20 April, 1 May	53.6	193	141	1150	132	6.30	9.97
6 May, 7 May, 18 May	49.7	191	170	1190	168	7.05	9.15
22 May, 23 May, 1 June	41.3	191	162	1220	178	7.23	7.59
8 June, 8 June, 16 June	31.5	185	199	1360	183	7.95	5.58
LSD (0.05)	2.3	1	12	30	13	0.29	0.38
Sugar beet genotype (G)							
American Crystal 190	45.2	193	168	1200	155	6.91	8.44
American Crystal 191†	50.1	193	226	1210	169	7.39	9.36
American Crystal 203	48.0	187	186	1070	174	6.78	8.75
American Crystal 305	43.6	197	169	1160	152	6.74	8.29
Betaseed 8422†	46.1	192	155	1240	148	6.88	8.58
Betaseed 9432	46.6	196	166	1220	143	6.80	8.87
Betaseed 9G6915	48.8	193	187	1310	152	7.35	9.02
Holly 50†	47.2	188	147	1270	161	7.12	8.58
Holly 59	44.4	195	159	1210	150	6.82	8.38
Holly 83†	45.6	189	153	1270	162	7.16	8.32
Holly 91C143041	48.6	183	193	1250	144	7.06	8.52
Hilleshog MonoHy 1	42.9	192	153	1260	168	7.20	7.99
Hilleshog MonoHy 2	47.2	193	185	1290	158	7.34	8.81
Hilleshog MonoHy 3	46.1	189	141	1160	191	7.11	8.42
Hilleshog MonoHy R2†	50.3	183	157	1260	198	7.61	8.91
Hilleshog MonoHy S91	49.0	189	134	1210	138	6.55	9.04
Seedex 9111A	49.5	186	141	1240	196	7.44	8.83
Seedex 9112I	46.5	186	162	1210	184	7.27	8.36
LSD (0.05)	2.0	2	14	30	14	0.28	0.38
Harvest date (H)							
10 September	41.1	178	199	1290	150	7.28	7.03
24 September	46.2	197	180	1280	178	7.52	8.75
8 October	51.1	191	166	1190	172	7.06	9.42
22 October	49.8	196	125	1150	153	6.50	9.45
LSD (0.05)	1.0	1	5	10	4	0.08	0.20
				ANOVA			
P × G	**	NS	*	*	NS	*	*
P × H	**	**	**	**	**	**	**
G × H	NS	NS	**	NS	*	NS	NS
P × G × H	NS	NS	NS	NS	NS	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† Commercial cultivars approved by the Grower-Western Sugar Joint Research committee for the C area.

strategies. Most plant breeders would agree that genotype × harvest date interactions should exist for sugar beet performance; i.e., specific genotypes should perform better early in the harvest season, while other genotypes would perform better later in the harvest season.

The objective of this experiment was to describe the relationships of sugar beet yield and quality response to harvest date, with emphasis on the management effects of planting date and genotype. Producers can use these results to determine the economic implications of replanting or early harvest decisions on sugar beet yield and quality.

MATERIALS AND METHODS

Experiments were conducted at the University of Wyoming Research and Extension Center near Powell, WY, during 1992 and 1993. The soil was a Garland clay loam (fine-loamy over sandy or sandy-skeletal, mixed, mesic Typic Haplargids). Management practices were typical of those utilized commercially in many furrow-irrigated mountain valleys of the western United States.

Preplant soil samples from the 0- to 30-cm depth were analyzed for residual nutrient levels. Soil-test K is typically high in this soil and was not analyzed. In 1992, soil was sampled on 20 March from a field where the previous crop was barley, *Hordeum vulgare* L. Soil test results were: organic matter, 15 mg g^{-1}; pH, 7.9; NO_3–N, 5 μg g^{-1}; and P, 12 μg g^{-1}. In 1993, soil was sampled on 15 March from a field where the previous crop was sugar beets. Soil test results were: organic matter, 16 mg g^{-1}; pH, 7.7; NO_3–N, 8 μg g^{-1}; and P, 16 μg g^{-1}. In each year, the soil in the study area was prepared for planting by fall plowing, disking, and roller harrowing followed by spring leveling and roller harrowing. Fertilizer was applied preplant at 140 kg N ha^{-1} and 112 kg P_2O_5 ha^{-1} and side dressed with 84 kg N ha^{-1} in the form of urea ammonium nitrate (280 g kg^{-1} solution) at the 10- to 12-leaf stage. On 27 Mar. 1992, ammonium nitrate (34–0–0 N–P–K) and triple superphosphate (0–46–0) were broadcast preplant. For the 1993 experiments, ammonium nitrate (34–0–0), diammonium phosphate (18–46–0), and ammonium sulfate (16–0–0–20 N–P–K–S) were applied preplant on 5 April.

Sugar beet seed was planted 2 cm deep in rows 56 cm apart at a seeding rate of 12.8 seeds m^{-2}. Stands were hand-thinned to an average harvested plant density of 70 000 plants ha^{-1}. Duration of the furrow irrigations was sufficient to refill the soil profile to field capacity (12- to 24-h sets) and, at six to seven times per growing season, irrigation frequency was enough to prevent significant plant water stress.

Weeds were controlled using the herbicides desmedipham {ethyl [3-[[(phenylamino) carbonyl]oxy]phenyl]carbamate}, diethatyl-ethyl]-N-(chloroacetyl)-*N*-(2,6-diethylphenyl)glycine],

Table 2. Planting date, genotype and harvest date effect on yield and quality of sugar beet grown at Powell, WY, during 1993.

Production factor	Root yield	Sugar content	Brei impurities			Sucrose loss to molasses	Recoverable sucrose
			Na	K	Amino-N		
	Mg ha^{-1}	g kg^{-1}	mg kg^{-1}			g kg^{-1}	Mg ha^{-1}
Planting, first irrigation, and emergence dates (P)							
7 April, 22 April, 6 May	46.7	173	256	1420	203	8.71	7.68
22 April, 22 April, 6 May	50.8	173	276	1450	220	9.10	8.33
3 May, 6 May, 18 May	46.3	167	366	1570	268	10.59	7.24
18 May, 21 May, 30 May	38.0	166	389	1610	262	10.75	5.90
3 June, 7 June, 19 June	33.1	164	385	1690	253	10.86	5.09
LSD (0.05)	2.8	3	36	30	22	0.41	0.43
Sugar beet genotype (G)							
American Crystal 190	39.8	172	344	1490	236	9.77	6.49
American Crystal 191†	43.0	172	420	1530	251	10.48	6.98
American Crystal 203	42.1	168	341	1370	249	9.52	6.70
American Crystal 305	39.4	173	350	1430	227	9.49	6.48
Betaseed 8422†	42.7	173	336	1560	226	9.85	7.01
Betaseed 9432	40.8	173	329	1550	215	9.63	6.67
Betaseed 9G6915	42.7	171	375	1620	223	10.21	6.86
Holly 50†	44.8	171	286	1550	237	9.73	7.25
Holly 59	38.4	172	349	1510	234	9.84	6.28
Holly 83†	43.6	171	299	1520	230	9.60	7.07
Holly 91C143041	43.1	159	437	1540	203	9.98	6.42
Hilleshog MonoHy 1	38.8	172	316	1610	259	10.37	6.28
Hilleshog MonoHy 2	41.2	168	384	1650	246	10.64	6.49
Hilleshog MonoHy 3	41.8	169	276	1470	270	9.82	6.67
Hilleshog MonoHy R2†	49.8	164	308	1610	270	10.45	7.74
Hilleshog MonoHy S91	42.5	169	255	1580	204	9.24	6.81
Seedex 9111A	47.5	163	316	1610	291	10.76	7.24
Seedex 9112I	49.7	159	306	1660	266	10.55	7.39
LSD (0.05)	2.6	3	33	60	21	0.58	0.40
Harvest date and day of year (H)							
14 September	41.1	152	452	1700	252	11.23	5.78
28 September	39.6	176	310	1560	231	9.80	6.58
19 October	46.3	175	264	1410	240	9.18	7.66
28 October	50.5	183	251	1430	243	9.23	8.74
LSD (0.05)	1.0	1	10	20	6	0.15	0.17
				ANOVA			
P × G	NS	NS	NS	NS	NS	NS	NS
P × H	**	**	**	**	**	**	*
G × H	**	NS	NS	NS	NS	NS	NS
P × G × H	NS	NS	NS	NS	NS	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† Commercial cultivars approved by the Grower-Western Sugar Joint Research committee for the C area.

ethofumesate [(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate], and phenmedipham{3-[(methoxycarbonyl)amino]phenyl(3-methylphenyl)carbamate}. A tank mixture of ethofumesate and diethatyl-ethyl was applied prior to planting in an 0.18-m band at the rate of 2.2 + 2.2 kg a.i. ha^{-1} and immediately incorporated using a power rotary tiller. Phenmedipham and desmedipham were applied postemergence at 0.28, 0.37, and 1.12 kg a.i. ha^{-1} when plants were at the cotyledon, 2-, and 4-leaf sugar beet growth stages. In addition, plots were hand-weeded to control escape weeds. Aldicarb [2-methyl-2-(methylthio) propionaldehyde *O*-(methylcarbamoyl) oxime] granules were applied preplant at the rate of 11.2 kg a.i. ha^{-1} to control the sugar beet root maggot, *Tetanops myopaeformis* (von Röder).

The experimental design was a randomized complete block in a split-plot arrangement with plot measurement over time and four replications (Gomez and Gomez, 1984). Main plots were planting dates, at approximately 2-wk intervals. Split plots were 18 genotypes requested from sugar beet seed companies and selected to represent a range in germplasm likely to express an interaction with harvest date. Five of these genotypes were approved for the production area by the Grower–western Sugar Joint Research committee. Split plots were nine rows wide and measured 7.6 m long. Alternating rows served as borders between harvested experimental rows. Plots were thinned and later checked for doubles and late germinating seed. Sugar beets were harvested between 10 September and 22 October at 14-d intervals during 1992 and between 14 September and 28 October at 9- to 21-d intervals during 1993. On each harvest date, using alternating rows as buffers, sugar beets within the experimental unit of one 3.05-m row section of each plot were hand-topped and lifted.

The sampled row section was measured for plant density, tare, root fresh mass, sucrose content, and purity parameters by the Western Sugar Company in Billings, MT. Purity parameters were measured by freezing brei samples and later analyzing for Na and K by flame photometry (William, 1984) and for amino-N by ninhydrin procedures (Quinn et al., 1974; Lawrence and Grant, 1963). Sucrose loss to molasses was calculated using a modified Carruthers and Oldfield (1960) formula. All measurements were calculated on a fresh weight basis (e.g., sucrose content = grams of sucrose per kilogram of fresh roots).

Treatment mean comparisons were made using least significant difference when *F*-values were significant ($P \leq 0.05$). Stepwise regression was used to describe relationships between measured variables and treatment levels. Linear, quadratic, and cubic coefficients were sequentially added to the model and included when they contributed significantly ($P \leq 0.15$) to the variation in the dependent variable. The chi-

Table 3. Emergence date and harvest date interaction effect on yield and quality of sugar beet grown at Powell, WY, during 1992 and 1993. Values are averaged across geontype and ranked by recoverable sucrose yield.

Emergence date	Harvest date	Growing season length	Root yield	Sugar content	Brei impurities			Sucrose loss to molasses	Recoverable sucrose
					Na	K	Amino-N		
		d	Mg ha^{-1}	g kg^{-1}	mg kg^{-1}			g kg^{-1}	Mg ha^{-1}
1992									
1 May	8 Oct.	160	60.2	194	152	1140	140	6.42	11.25
1 May	22 Oct.	174	58.7	197	125	1120	141	6.24	11.19
1 May	24 Sep.	146	54.9	200	158	1220	152	6.89	10.57
18 May	8 Oct.	143	55.3	192	168	1160	177	7.04	10.22
18 May	22 Oct.	157	53.0	197	130	1110	161	6.51	10.08
1 May	10 Sep.	132	51.5	181	176	1230	140	6.84	8.95
18 May	24 Sep.	129	47.2	197	175	1250	175	7.37	8.91
1 June	22 Oct.	143	44.6	197	112	1140	155	6.43	8.46
1 June	8 Oct.	129	44.9	191	170	1190	201	7.47	8.22
1 June	24 Sep.	115	41.7	197	177	1260	199	7.73	7.87
18 May	10 Sep.	115	43.5	178	208	1240	159	7.29	7.39
16 June	22 Oct.	128	34.2	192	134	1250	168	7.06	6.31
16 June	8 Oct.	114	34.7	187	189	1310	199	7.95	6.20
1 June	10 Sep.	101	34.0	179	190	1280	158	7.33	5.84
16 June	24 Sep.	100	32.2	191	230	1430	214	8.74	5.80
16 June	10 Sep.	86	25.0	170	243	1450	153	8.10	4.03
LSD (0.05)			2.5	2	12	30	10	0.22	0.48
1993									
18 May	28 Oct.	163	57.5	180	290	1510	292	10.31	9.69
6 May	28 Oct.	175	54.0	186	201	1320	200	8.05	9.57
6 May	19 Oct.	166	53.1	177	216	1320	208	8.23	8.90
18 May	19 Oct.	154	47.1	177	271	1400	253	9.33	7.88
30 May	28 Oct.	151	46.4	179	309	1520	290	10.41	7.82
6 May	28 Sep.	145	44.9	180	238	1440	201	8.65	7.69
6 May	14 Sep.	131	46.7	159	364	1580	230	10.12	6.93
18 May	28 Sep.	133	42.1	174	336	1550	245	10.07	6.87
19 June	28 Oct.	131	38.2	181	272	1550	247	9.78	6.54
30 May	19 Oct.	142	39.5	173	294	1450	255	9.66	6.47
18 May	14 Sep.	119	46.4	148	513	1790	300	12.45	6.27
19 June	19 Oct.	122	38.6	170	320	1570	274	10.42	6.18
30 May	28 Sep.	121	35.0	175	357	1640	251	10.54	5.72
30 May	14 Sep.	107	37.3	147	534	1770	272	12.11	5.01
19 June	28 Sep.	101	31.1	171	381	1750	255	11.09	4.94
19 June	14 Sep.	87	28.3	146	486	1770	230	11.34	3.77
LSD (0.05)			2.4	3	24	40	14	0.36	0.39

square test (Gomez and Gomez, 1984) was used to verify homogeneity of variance before combining data. For the combined analysis, all September harvest dates were averaged and compared with the average of all October harvest dates. Planting dates were grouped according to emergence date.

RESULTS

In northwestern Wyoming, early spring precipitation is usually not sufficient for sugar beet seed germination and growth to emergence. Irrigation water delivery is usually scheduled for about 20 April. In both years, the earliest planted beets emerged on the same date as those of the second planting date (Tables 1 and 2). Planting date treatments are reported in Tables 1 and 2; Table 3 and Fig. 1 and 3 combine the first two planting dates, with plant emergence date as the independent variable.

No planting date × genotype × harvest date interaction was observed in any year for any yield or quality measurement (Tables 1 and 2). Planting date × genotype and genotype × harvest date interactions were not consistent between years for yield and quality measurements. Planting date × harvest date interactions were observed in both years for every sugar beet yield and quality measurement. In both years, regardless of planting date, later harvest date resulted in greater root yield, sugar content, and recoverable sucrose, while sucrose loss to molasses and brei impurities decreased (Table 3).

1992

Overall, 1992 can be characterized as a good to excellent year for sugar beet yield and quality. Most producers, and the factory district as a whole, realized record yields with high sugar content. Sugar beets emerging on 1 May produced 44% more root yield at harvest than beets emerging 16 June (Table 1). Later sugar beet emergence decreased sugar content at harvest by 4%, from 193 to 185 g kg^{-1}. Delayed plant emergence increased sucrose loss to molasses 15%, from 6.60 to 7.75 g kg^{-1}, with all brei impurities increasing. Later emergence date decreased recoverable sucrose 47%, from 10.49 to 5.58 Mg ha^{-1}, and averaged 0.10 Mg ha^{-1} d^{-1}. Delaying plant emergence from 1 May to 18 May decreased recoverable sucrose 0.07 Mg ha^{-1} d^{-1}; delaying planting from 1 June to 16 June decreased it 0.13 Mg ha^{-1} d^{-1}. Differences between high- and low-performing genotypes for root yield, sugar content, sucrose loss to molasses, and recoverable sucrose were 7.4 Mg ha^{-1}, 14 g kg^{-1}, 1.06 g kg^{-1}, and 1.37 Mg ha^{-1}, respectively. Delaying harvest increased root yield 20%, from 41.1 Mg ha^{-1} on 10 September to 51.1 Mg ha^{-1} on 8 October. Delaying harvest increased sugar content from 178 g kg^{-1} on 10 September to 196 g kg^{-1} on 22 October; however, the maximum sugar content was observed on 24 September possibly due to the effects of soil water content (Carter et al., 1980). Delayed harvest decreased

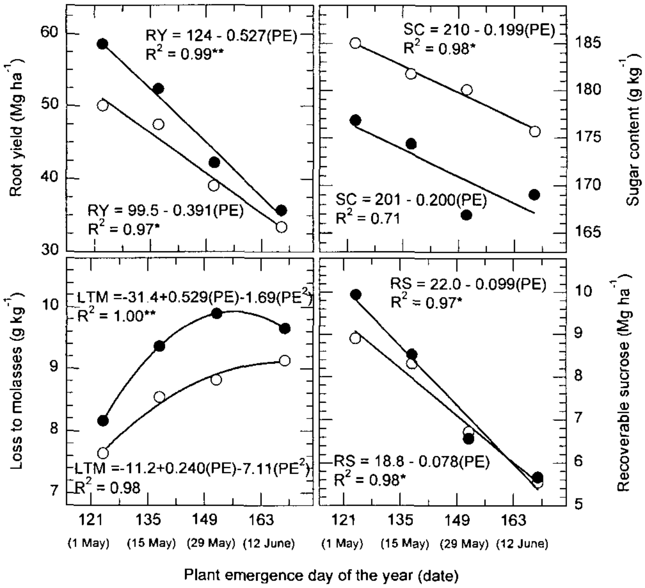

Fig. 1. Relationship between plant emergence (PE) and root yield (RY), sugar content (SC), loss to molasses (LTM), and recoverable sucrose (RS) for the sugar beet cultivars BetaSeed 8422 (open symbols) and Hilleshog MonoHy R2 (solid symbols). Data are averaged across 1992 and 1993.

sucrose loss to molasses from 7.28 g kg^{-1} on 10 September to 6.50 g kg^{-1} on 22 October. Later harvest increased recoverable sucrose 25%, from 7.03 to 9.45 Mg ha^{-1}. Between September harvests, recoverable sucrose increased 0.12 Mg ha^{-1} d^{-1}, while between October harvests the increase was 0.002 Mg ha^{-1} d^{-1}.

1993

In 1993, a series of October storms occurred, with snow and cold temperatures. Sucrose loss to molasses was higher than normal, and piling and storage problems occurred because of beet injury due to freezing. When sugar beet emergence was delayed from 6 May to 19 June, root yield at harvest decreased by 32%, from 48.8 to 33.1 Mg ha^{-1} (Table 2). Later sugar beet emergence decreased sugar content at harvest by 5%, from 173 to 164 g kg^{-1}. Delayed plant emergence increased sucrose loss to molasses 20%, from 8.71 to 10.86 g kg^{-1}, with all brei impurities increasing. Later emergence date decreased recoverable sucrose from 8.01 to 5.09 Mg ha^{-1}, and was linear at the rate of 0.07 Mg ha^{-1} d^{-1}. Differences between high- and low-performing genotypes for root yield, sugar content, sucrose loss to molasses, and recoverable sucrose were 11.4 Mg ha^{-1}, 14 g kg^{-1}, 1.52 g kg^{-1}, and 1.46 Mg ha^{-1}, respectively. Delaying harvest increased root yield 19%, from 41.1 Mg ha^{-1} on 10 September to 50.5 Mg ha^{-1} on 28 October. Delaying harvest increased sugar content 17%, from 152 g kg^{-1} on 10 September to 183 g kg^{-1} on 28 October. Delayed harvest decreased sucrose loss to molasses from 11.23 g kg^{-1} on 10 September to 9.23 g kg^{-1} on 28 October. Later harvest increased recoverable sucrose 34%, from 5.78 to 8.74 Mg ha^{-1}. Between September harvests, recoverable sucrose increased 0.06 Mg ha^{-1} d^{-1}, while between October harvests the increase was 0.009 Mg ha^{-1} d^{-1}.

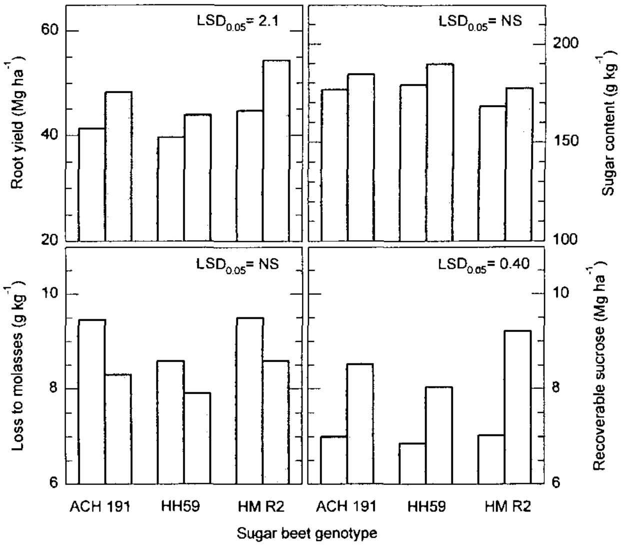

Fig. 2. Performance of three sugar beet cultivars during September (open bars) and October (shaded bars) harvest periods. Data are averaged across 1992 and 1993.

1992 and 1993 Combined Analysis

When averaged across all years, genotypes, and harvest dates, a delay in emergence of 46 d decreased root yield 38%, from 52.5 to 32.3 Mg ha^{-1}; sugar content decreased 4%, from 183 to 175 g kg^{-1}; and recoverable sucrose decreased 42%, from 9.25 to 5.34 Mg ha^{-1} (average of Tables 1 and 2). Loss to molasses increased 21%, from 7.75 to 9.41 g kg^{-1}.

Root yield varied 18% among sugar beet genotypes (range 40.9–50.1 Mg ha^{-1}), sugar content varied 6% (173–185 g kg^{-1}), loss to molasses varied 13% (7.90–9.10 g kg^{-1}), recoverable sucrose varied 14% (7.14–8.33 Mg ha^{-1}) (average of Tables 1 and 2). Hilleshog MonoHy R2 had the greatest recoverable sugar averaged over years.

Over the 43-d harvest period, root yield increased 22%, from 41.1 to 50.2 Mg ha^{-1}; sugar content increased 15%, from 165 to 190 g kg^{-1}; and recoverable sucrose increased 45%, from 6.41 to 9.28 Mg ha^{-1} (average of Tables 1 and 2). Loss to molasses decreased 21%, from 9.10 to 7.12 g kg^{-1}.

The relationship between sugar beet yield and quality response and plant emergence date is described for two of the commercially available sugar beet cultivars (Fig. 1). The nature of the genotype × harvest date interaction for three of the commercially available sugar beet cultivars is described in Fig. 2. These cultivars represent the range of performance among all 18 genotypes, with the other genotypes falling between these representative extremes.

Hilleshog MonoHy R2 gained significantly more root yield between September and October harvests than American Crystal 191 or Holly 59 (Fig. 2). Changes in sugar content and loss to molasses between September and October harvests were similar among all 18 geno-

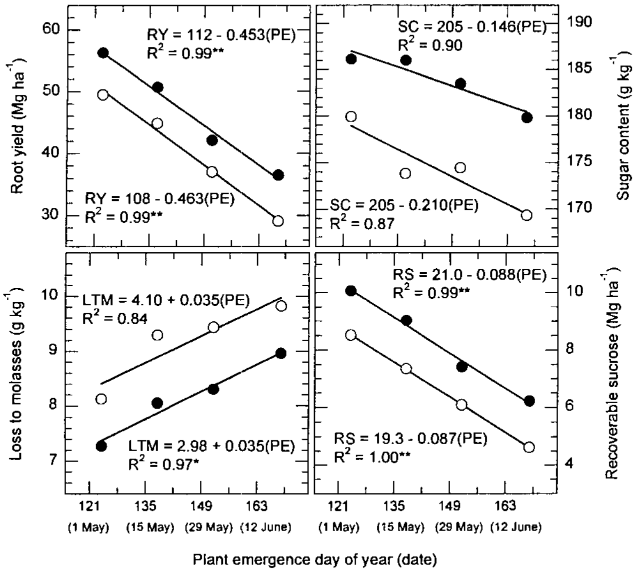

Fig. 3. Relationship between plant emergence (PE) and root yield (RY), sugar content (SC), loss to molasses (LTM), and recoverable sucrose (RS) for September (open symbols) and October (solid symbols) harvest periods. Data are averaged across 1992 and 1993.

types; thus, Hilleshog MonoHy R2 produced more recoverable sucrose in October.

Hilleshog MonoHy R2 produced greater root yield than Betaseed 8422 on every plant emergence date, but its sugar content was lower and loss to molasses was greater (Fig. 1). Averaged over all harvest dates, recoverable sucrose was greater for Hilleshog MonoHy R2 than Betaseed 8422 when planted on the earliest date, but with later emerging dates there was no difference between these sugar beet genotypes.

In the combined analysis, no interactions were observed between different planting dates and harvest dates (Fig. 3). Earlier planting dates produced greater recoverable sucrose than later planting dates, regardless of when they were harvested during the fall. Likewise, October harvest dates performed better than September harvest dates. The 1 May planting dates harvested in September yielded as much recoverable sucrose as 22 May planting dates harvested in October. Recoverable sucrose decreased 0.09 Mg ha^{-1} for each day's delay in planting date.

DISCUSSION

In both years, sugar beet emergence took place only after irrigation. Planting 2 to 3 wk prior to irrigation did not affect sugar beet yield and quality compared with planting and irrigating immediately.

All planting dates after the first irrigation on 20 April resulted in poorer sugar beet yield and quality. The earliest planting dates not only produced the best yield and quality, but they have also been shown to decrease the incidence of infection by beet yellows virus (BYV) and beet western yellows virus (BWYV) (Hills et al., 1969) and by *Polymyxa betae* Keskin, the fungal vector of beet necrotic yellow vein virus (BNYVV), the causal agent of rhizomania disease (Blunt et al., 1992).

Differences between the five planting dates were similar on each harvest date. Sugar beets planted on 8 June were not economical, given the grower–processor contract payment schedule and production costs when the study was conducted. Sugar beets planted on 22 May did not recover production costs unless harvested after 24 September. Sugar beets planted between 30 March and 6 May could be harvested at any time and production costs would still be recovered (Held et al., 1994).

When stand reductions occur following optimum planting dates, due to poor emergence or some type of injury, the decision to replant should be based on the yield potential of the reduced stand vs. the yield potential of a late planted stand (Burcky and Winner, 1986; Smit, 1993). Replanting decisions must incorporate the costs of extra tillage, planting, and seed, and of additional pesticides that may be required. Rain may also delay replanting if the field is reworked. Replanting costs can be reduced by replanting at a low seeding rate alongside or over the original row, to fill in the stand without tearing it up. However, although this option saves costs, uneven within-row plant spacing may be a problem. There is no guarantee that replanting will result in a full stand. Diseases, insects, or herbicide injury such as reduced the original stands may again cause reduction in replanted sugar beets.

Among the commercial genotypes used in this study, Hilleshog MonoHy R2 represents a sugar beet genotype that has above-average root yield with lower than average sugar content. American Crystal 191, Betaseed 8422, Holly 50, and Holly 83 represent genotypes with average root yield and higher than average sugar content.

The length of the growing season affected the expression for genotypic differences in yield and quality. In 1992, genotypic differences for yield and quality were greater for early planting dates than for later planting dates (Table 1, ANOVA). There were no differences for recoverable sucrose between genotypes harvested during September, but differences were observed for October harvests (Fig. 2). Hilleshog MonoHy R2 performed best of all genotypes when planted early and harvested late. Producers should consider planting genotypes such as Hilleshog MonoHy R2 in fields where they know they will plant early and harvest late, taking advantage of the entire growing season, and use genotypes with average root yield and above-average sugar content for late planted or early harvested fields.

Sugar beet performance improved with later harvest date and was similar to previous reports (Lauer, 1994, 1995). Recoverable sucrose increased 0.07 Mg ha^{-1} for each day's delay in harvest date between September and October. Delaying harvest tended to increase sugar content, but sugar content tended to decrease following an irrigation at the study area during the harvest period (Carter et al., 1980). Delayed harvest would often decrease sucrose loss to molasses, but weather events such as frost or cold temperatures can also influence loss to molasses.

The relationships between dates of planting, as well as September and October harvest periods, and yield and quality was linear and nearly parallel (Fig. 3). Thus, based on this study, planting date had no bearing on the decision to harvest early or late. The length of the growing season is most important (Table 3). Early planting and late harvest produced greatest recoverable sucrose. Delaying harvest by 1 mo was the same as delaying planting by 18 d for recoverable sucrose (Fig. 3 and Table 3).

Producers are most interested in recoverable sucrose, while processors are most interested in sugar loss to molasses. From a producer's perspective, sugar beet genotypes performed the same throughout the harvest period. Recoverable sucrose ranking of genotypes at the beginning of harvest was similar at the end of harvest. From a processor's perspective, sugar beet genotypes performed differently, depending on harvest date. Sucrose loss to molasses changed at different rates during harvest, although the magnitude of these changes was small. One explanation for the small genotype × harvest date interaction is that sugar beet seed companies do extensive testing under diverse climatic, management, and harvest conditions and that commercialized genotypes rank similarly regardless of harvest date. The current cultivar approval system does not reward cultivar development for early vs. late harvest maturation.

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